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Review

Face mask ventilation – the dos and don'ts

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S U M M A R Y

Face mask ventilation provides respiratory support to newly born or sick infants. It is a challenging technique and difficult to ensure that an appropriate tidal volume is delivered because large and variable leaks occur between the mask and face; airway obstruction may also occur. Technique is more important than the mask shape although the size must appropriately fit the face. The essence of the technique is to roll the mask on to the face from the chin while avoiding the eyes, with a finger and thumb apply a strong even downward pressure to the top of the mask, away from the stem and sloped sides or skirt of the mask, place the other fingers under the jaw and apply a similar upward pressure. Preterm infants require continuous end-expiratory pressure to facilitate lung aeration and maintain lung volume. This is best done with a T-piece device, not a self-inflating or flow-inflating bag.

1. Introduction

Face mask ventilation is the most important technique in the initial resuscitation and stabilisation of newly born infants, and is taught in all neonatal resuscitation courses.

Face mask ventilation aims:

- to provide positive pressure ventilation (PPV) for newly born infants who are apnoeic or have inadequate breathing;
- to facilitate the clearance of lung fluid, aerate the lungs, establish and maintain a functional residual capacity (FRC) and thereby ensure oxygenation as soon as possible after birth.

Mask ventilation is a difficult technique to master and ensure appropriate tidal volume delivery. The problems [1–4] are as follows.

- Mask leak is very common and varies a lot during resuscitation.
- Masks are difficult to hold on the face in a way that ensures a leak-free seal.
- With a very large leak the tidal volume delivered may be too small.
- If there is little or no leak the tidal volumes may be dangerously large.
- Pushing the mask too hard with poor technique may obstruct gas flow.

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2. Face masks

There are many shapes of mask. Most are round with a cushioned rim. Some are triangular, called 'anatomically' shaped. Older designs have a flat, uncushioned rim.

Several things need to be known before using face masks:

- The mask must be the right size. It must extend from the chin tip and not encroach on the eyes. Therefore, one size will not fit all babies [5].
- There is little evidence that different shaped masks are better than others at forming a seal on the face [6]. However, a soft and flexible edge does help form a seal. A firm top that does not indent when held on the face is preferable. The Rendell-Baker mask has a firm edge, reportedly making it difficult to get a good seal [7].
- More important than the shape is how it is used [5,6,8].

2.1. Gas leak between the mask and face

We investigated mask leak with different masks and staff of varying experience. We made the Laerdal Resusci Baby manikin leak-free by replacing the original 'lung' with a 50 ml Dräger test lung connected by non-distensible tubing to the mouth by an airtight seal [9].

Mask leak was measured with a flow sensor between the resuscitation device and mask to measure flow going through the mask into the manikin and then back through the mask. Flow was integrated to give tidal volume. The difference between the inflation flow and expiration flow was mask leak [6,9].

We found that mask leak often exceeded 50% with some participants having 100% leak and not ventilating the manikin, whereas others had almost no leak. It was similarly high and variable with different masks and between professional categories (Fig. 1) [5,6]. More recent work corroborates these findings across a broader range of modern and preterm designs [10,11].

2.2. Techniques of positioning and holding a mask on the face

While investigating how to minimise mask leak [12] we found that holding the mask stem between the index finger and thumb was least effective, as it was difficult to achieve a balanced downward pressure and jaw lift. With a Laerdal mask, the 'two-point top-hold', with good jaw lift, was most effective. The 'OK rim hold' was most effective with the 60 mm Fisher and Paykel mask because this stabilised the pliable top (Figs. 2 and 3).

Of the mask techniques tested we have found that the two-point top-hold is the single resuscitator technique that most reliably reduces mask leak (watch http://www.youtube.com/watch?v=_THhS26OsA).

- Roll the mask on to the face rather than placing it straight down. This is done by positioning a finger on the baby's chin tip to align the mask edge [12] ensuring that it is not extended beyond the chin, then gently rolling it upwards on to the face ensuring it is not encroaching on the eyes. A mask over the orbits will not seal well and may damage the eyes.
- Check that the mask is positioned evenly on the face when viewed from above and side, being upright and not tilted.
- For masks with a solid top, downward pressure must be applied evenly using an index finger and thumb, not touching the stem and not encroaching on the side of the mask. The index finger should be on the chin side. This is the 'two-point top-hold'. The finger and thumb should apply a firm pressure on the mask to ensure that it is sealed on the face.
- If the mask has a flexible top, then holding this with the index finger and thumb encircling the top outside edge of the mask helps stabilize the top and apply an even downward pressure [5]. This is the 'OK rim hold'.
- Fingers should not push on the skirt of the mask because this distorts it.
- The other fingers of the hand holding the mask should be placed under the jaw on that side to apply jaw lift; drawing the face upwards into the mask with a pressure equal to the downward force being applied.

2.3. Two-handed technique

There are several other techniques to apply a mask. However, the only one that reliably minimises leak is the two-handed technique [8,10,13]. This is similar to the two-point top-hold, with equal downward pressure on the top of the mask from the index fingers and thumbs with good jaw lift, but two hands are used.

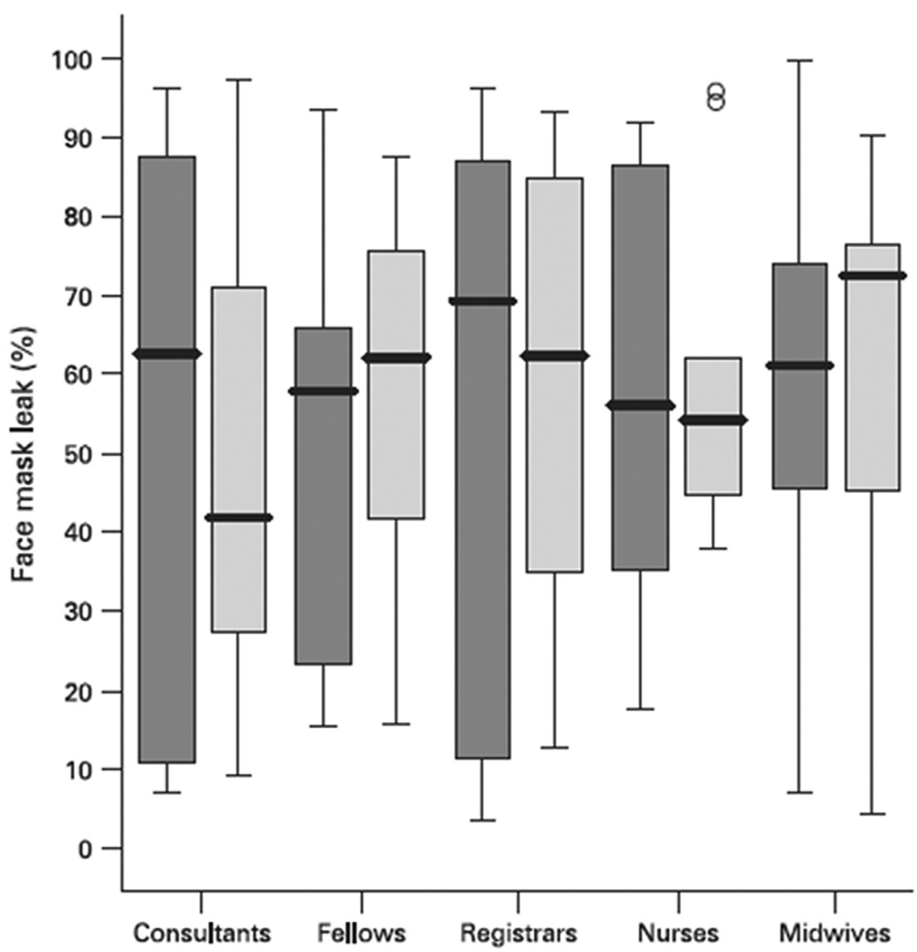

Fig. 1. The percentage leak at the face mask for two face masks: Laerdal size 0/1 (dark shading) and Fisher and Paykel 60 mm (light shading). Box plots show median values (solid lines), interquartile range of data and outliers (circles). From Wood et al [5].

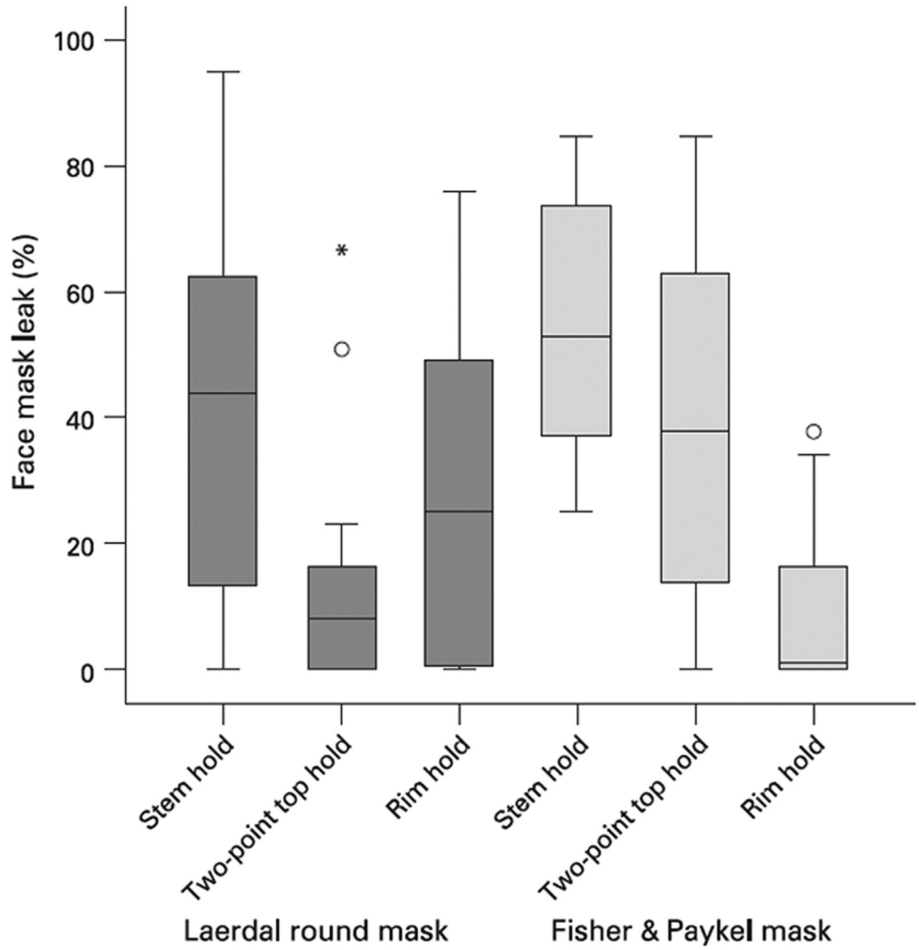

Fig. 2. Percentage leak at the face mask for two face masks: Laerdal size 0/1 (dark shading) and Fisher and Paykel 60 mm (light shading) and three hold type. Box plots show median values (solid lines), interquartile range (margins of box), range of data, outliers (circles) and extreme values (asterisk). From Wood et al [12].

2.4. Self-assessment of mask leak

During manikin studies, participants were asked to assess the amount of mask leak as: very small or nil, small, moderate, large, or very large. In the first three categories there was wide variation from <20% to 90%. However, in the large category the leak varied from 60% to 100%. For one mask no-one claimed to have a very large leak despite many exceeding 80%. No-one who claimed to have a very small or no leak had a leak <20% [5]. Resuscitators estimates of leak were similarly inaccurate in infant studies (Fig. 4).

3. Ventilation devices

3.1. Self-inflating bags (SIBs)

- These are bags of 240, 300, 450, or 500 ml capacity that refill quickly by recoil. The mask fits to one end and an oxygen supply and reservoir can be fitted to the other. They entrain room air and do not need compressed gas, so can be used in any setting. The bag refills even with a large mask leak. They have a blow-off valve that releases pressure if it rises above a preset

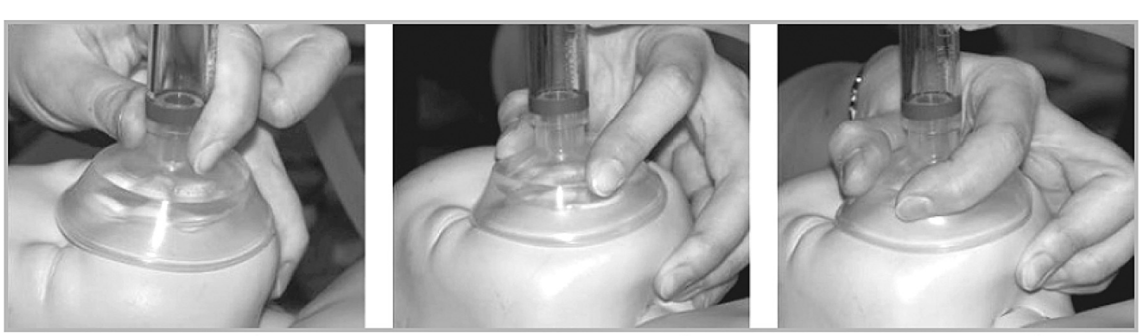

Fig. 3. Photographs of the three mask holds demonstrated on the Laerdal round neonatal mask size 0/1. From Wood et al [12].

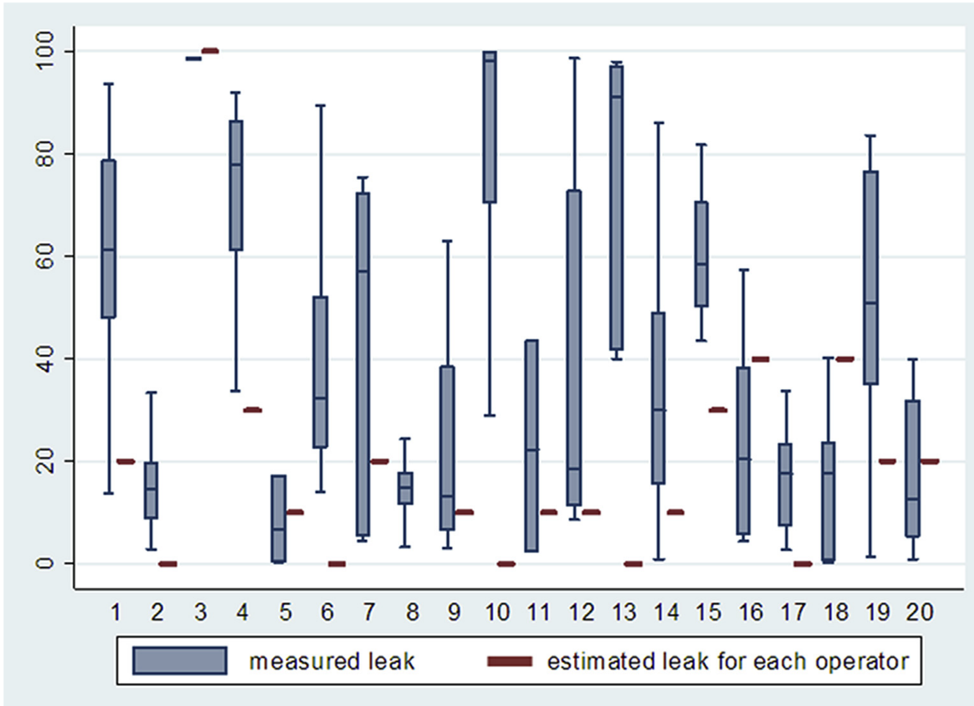

Fig. 4. Face mask leak for each inflation as a percentage of the inspired tidal volume for each of 20 infants during 30 s of positive pressure ventilation. Box plots show median (solid bar), interquartile range (margins of the box) and 95% confidence interval. The resuscitators' estimates of their median face mask leak are shown as short horizontal bars next to the leak for each infant. Adapted from Schmölzer et al [17].

level that varies by manufacturer (35–40 cmH_2O). Some have a pressure manometer attached.

- The tidal volume should be ~5–8 ml/kg. We have seen that to deliver these volumes, when there is a good mask seal, the bag should be gently squeezed between a thumb and just one or two fingers. A 500 ml bag could deliver too much volume, and so a 240 ml bag may be more appropriate.
- If the operator needs to empty the bag fully, this suggests a very large mask leak.
- The bag should be squeezed slowly to provide an inflation time aiming to match a spontaneous inspiratory time.
- Squeezing a bag hard and fast activates the blow-off valve, and much of the gas is lost rather than going to the baby.
- SIBs do not deliver positive end-expiratory pressure (PEEP) and so are not ideal for helping to form and maintain the FRC in a very preterm baby. A PEEP valve can be fitted but the pressure is not constant [14]. PEEP can only be provided if the bag is squeezed at least 40 times/min, but the level will vary with the rate.
- SIBs with a PEEP valve cannot deliver continuous positive airways pressure (CPAP) [14].
- It is difficult with SIBs to give a prolonged inflation of ≥10 s [15].

3.2. Flow inflating bag (FIB)

- These are ~500 ml floppy bags with the mask fitted at one end and a small open tube or valve at the other end. They have no in-built recoil and need a flow of gas into the bag to keep it inflated.
- They rely on a good mask seal to maintain bag pressure during expiration. The bag pressure is controlled by the tube at the far end being variably compressed by the little finger curled round it, or the valve adjusted.
- It requires experience and skill to maintain an end-expiratory pressure. There has to be little or no mask leak, which is difficult to achieve; the flow control at the back of the bag has to be carefully modulated to maintain an appropriate PEEP during expiration. This may cause the PEEP to rise too high or fall too low, particularly as leak changes.
- If the expiratory valve is closed too much the pressure can rise very high. Many have a built-in pressure blow-off valve to limit this. A manometer must be used.
- It is possible, in skilled hands, to deliver a prolonged inflation of ≥10 s but the pressure is variable.
- With FIBs it is not possible to sense the compliance or changing compliance of the lung and accordingly adjust the pressure required to ventilate a baby [16].

3.3. T-piece resuscitator

- It consists of a system to regulate and display the peak inflating pressure (PIP) and pressure release valves. It needs compressed gas. The gas leaves the system via flexible tubing to a T-piece that directs the gas into the mask. The T-piece has a variable screw valve to control the PEEP/CPAP level. Inflation is generated by transiently occluding this valve with a finger. The duration of the occlusion determines the inflation time. It can be used to provide a sustained inflation [17].
- Before resuscitation the gas flow, PIP and PEEP are set [18].
- Delivered pressures are more stable and accurate than with SIB or FIB.
- As it is pressurised throughout ventilation, any leak will be higher than with SIB.
- A T-piece is the only resuscitation device that can provide a consistent CPAP.
- Operators need to be aware: (1) if the infant is not responding the PIP may need to be increased. This is not as intuitive as squeezing a bag harder. (2) Once set, the flow must not be

changed during a resuscitation because PIP and PEEP will change.

4. Mask leak and tidal volumes during neonatal resuscitation

Studies with manikins have been criticised as having limited clinical applicability or relevance. However, several studies, measuring mask leak and tidal volumes, during resuscitations of preterm babies have shown almost exactly the same large and very variable leak (Fig. 4) [1,19].

With very variable leaks, the tidal volumes can vary from a damaging 30 ml/kg to so little that the lungs are not being inflated (Fig. 5) [20].

Reducing variation in mask leak enables more consistent ventilation, improving effectiveness and minimizing potential harm [17,20].

5. Pressure or tidal volume during ventilation?

During resuscitations tidal volume is not measured. Ventilation is guided by clinical assessment. However, this is inaccurate and hypocarbia may occur in about a quarter of preterm infants [3]. Lung injury has been demonstrated in preterm animals after only a few large tidal volume inflations [21].

Traditionally, pressure has been targeted but not tidal volume. Neonatal intensive care ventilators measure the tidal volume and may deliver a set tidal volume (usually 4–6 ml/kg). This 'volume-targeted' approach has benefits compared to pressure-limited ventilation and could assist resuscitations [22].

Resuscitation guidelines suggest that inflations use a PIP of ~20–30 cmH_2O, with limited supporting data. Term newborns can generate much higher negative pressures when aerating their lungs [23]. Achievement of a set PIP cannot be taken as proof of adequate tidal volume; however, failure to achieve a set pressure is proof of inadequate volume delivery. The relationship between pressure and tidal volume is weak and highly variable for several reasons [4] see Fig. 6:

- Some volume is lost from the mask before it enters the baby.
- Lung compliance and resistance varies so it is not possible for one PIP to deliver the optimal tidal volume for all babies.
- At birth the lung is full of fluid. Water has a much higher resistance through the airways than gas, so higher pressures may be required for the initial inflations but not subsequently.
- Many babies breathe during resuscitation and contribute to the tidal volume.
- Airway obstruction occurs during resuscitation and the PIP may not overcome this.

6. What is the appropriate tidal volume?

The appropriate tidal volume during resuscitation is not known accurately and so we have to extrapolate from experience with spontaneously breathing babies at birth, ventilated babies after birth, and animal studies.

For ventilated babies, with aerated lungs, a tidal volume of ~5 ml/kg, at a rate of 40–60/min, should provide adequate control of the partial pressure of CO_2 [22].

During the first inflations, where the fluid is moved out of the airways and an FRC is forming, tidal volumes may need to be larger. Studies of exhaled CO_2, at this time, have shown that no CO_2 was detected if the tidal volume was <5 ml/kg [24].

Studies of breathing preterm babies, immediately after birth, showed a mean tidal volume of about 6 (SD: 4) ml/kg [25,26]. In ventilated very preterm infants it is about 5 (SD 0.6) ml/kg [27,28].

Many resuscitated babies are overventilated and have a low partial pressure of arterial CO_2 when admitted to the neonatal intensive care [3]. These babies received tidal volumes ~9 ml/kg.

Preterm lamb studies have shown that a few inflations with tidal volumes of >15 ml/kg damaged the lungs with a systemic

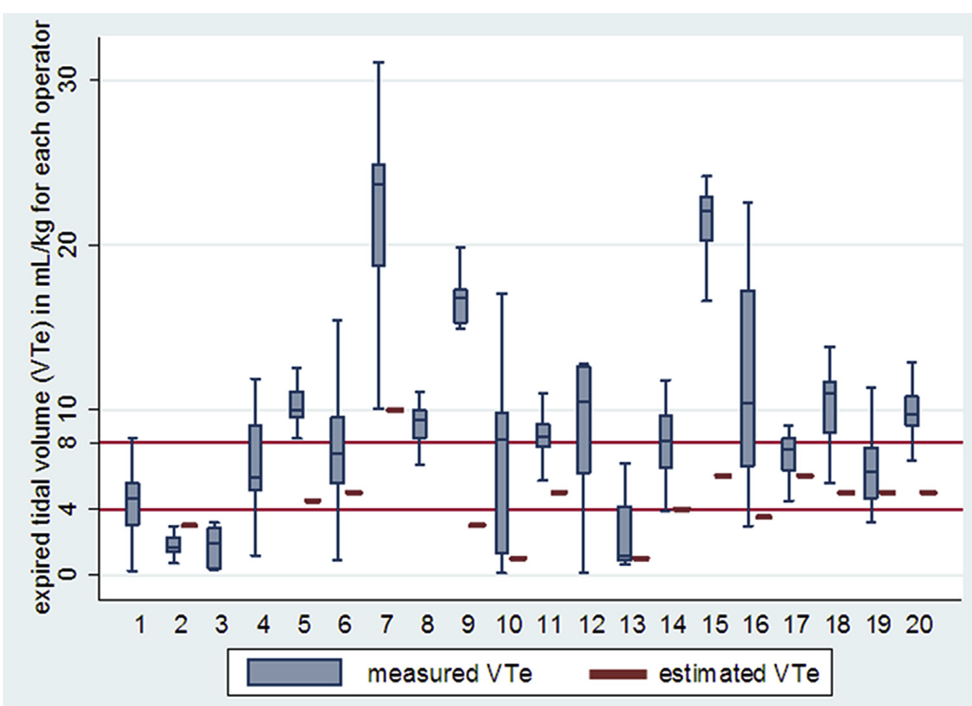

Fig. 5. Expired tidal volume for each inflation for each of 20 infants during 30 s of positive pressure ventilation. Box plots show median (solid bar), interquartile range (margins of the box) and 95% confidence interval. The resuscitators' estimates of their median expired tidal volume are shown as short horizontal bars next to the leak for each infant. Adapted from Schmölzer et al [17].

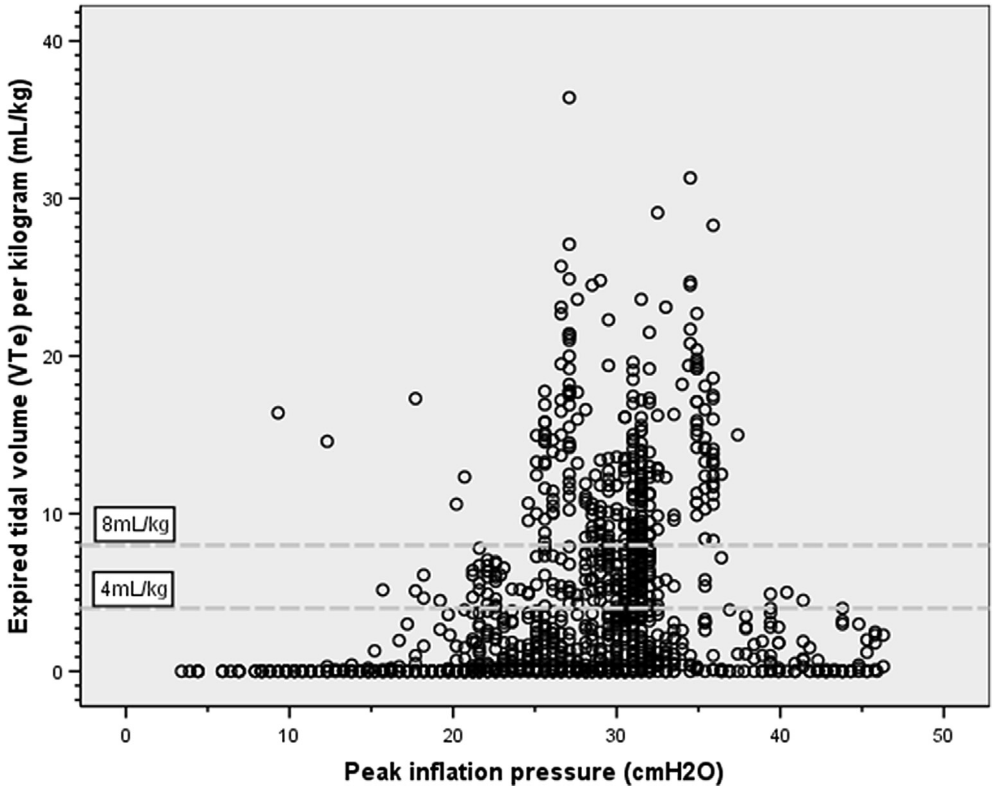

Fig. 6. Comparison of delivered expired tidal volume in ml/kg and peak inflation pressure during resuscitation of preterm infants. From O'Donnell [4].

inflammatory response [29]. This may be a problem for very preterm infants.

Currently it is not easy to measure, monitor and control tidal volume during resuscitation. However, this is now standard practice during neonatal ventilation and will almost certainly be used in the future to guide resuscitation.

7. Observing chest movement to assess ventilation

Resuscitators guide their inflations by observing chest wall movement. The ability of resuscitators to assess this accurately, and particularly the tidal volumes delivered, has been assessed and measured [30]. The chest moved with most inflations but the resuscitation team could not accurately assess the tidal volume being delivered.

8. Airway obstruction

There are times when little or no gas flows into the lungs. This may be because of inadequate PIP and stiff lungs, or obstruction to the gas flow.

The reasons for airway obstruction are not known. It has been speculated that it might be due to an unsatisfactory chin and neck position. The 'neutral head position' and 'sniffing' position using mild extension of the neck are taught; although there is little evidence for this during mask ventilation some neck extension is often needed if a baby needs intubating [31].

The possible causes of airway obstruction are:

- the tongue obstructing the pharynx;
- laryngeal adduction;
- excess pressure from the mask blocking the nose and mouth;
- the jaw being pushed backwards or neck flexion from the pressure on the mask.

The four practical responses to airway obstruction are:

- ensure that the neck is in a position to 'open the airway';
- check the mask size, position and hold;
- increase the inflating pressure;
- use an expired CO_2 detector to assess effectiveness of ventilation;
- pass an endotracheal tube.

9. Colorimetric CO_2 devices with mask ventilation

A colorimetric CO_2 detector is recommended during endotracheal intubation to detect whether the endotracheal tube is in the trachea and ventilation is being achieved, by the detection of CO_2 in the exhaled gas. It detects expired CO_2 within about six inflations by a colour change from purple to yellow. These can be useful during mask ventilation to detect airway patency, obstruction or inadequate ventilation [32,33].

10. Laryngeal mask airways (LMAs)

An LMA is an alternative device for delivering pressure to the airways for a short time. It is a small inflatable silicone mask that fits over the larynx, with a connecting tube. It is passed through the mouth without the need for a laryngoscope. Once inserted, a cushioned rim is inflated to achieve a low-pressure seal around the laryngeal inlet. Like face masks they are not leak-free, especially at inflating pressures used during neonatal resuscitation. They are easier to place correctly than an endotracheal tube, even by inexperienced operators. The use of LMAs has been reported in case

series of term infants [34] and in small numbers of moderately preterm infants [35]. The smallest-sized LMA is too large to be used in very preterm infants. Successful use of LMAs in infants with upper airway anomalies has been reported [36].

11. Nasal tubes or face masks?

It has been suggested that a nasal tube, or tubes, may be more effective for resuscitating neonates than a face mask. If a single tube is used in one nostril, after the nasopharynx has been cleared of secretions, the other nostril and mouth must be held closed to prevent gas leaking. A large randomized controlled trial comparing face mask with a nasal prong during neonatal resuscitation has recently been completed [37]. There were no significant differences in any clinical outcome.

12. PEEP and CPAP during resuscitation

It has been shown both in animal experiments [38,39] and randomized controlled trials [40–43] that PEEP or CPAP facilitate the formation of an FRC and improve oxygenation. It therefore seems logical to resuscitate preterm infants with a device that delivers known levels of PEEP or CPAP if available.

13. Which gas flows should be used?

There is little research about the appropriate gas flow. Flows of 8–10 l/min are frequently used. The flow must be sufficient to supply the baby with an appropriate tidal volume particularly when taking a deep breath. However, it should not be too high because the rapid rise in pressure during inflation might cause shear stress [44].

14. Applied force to the face and head from a face mask

Some resuscitators push face masks on to the face very firmly. In manikins the force applied varied from 606 to 3717 g and was ~2000 g on average [45]. Having corroborated such findings in both term and preterm manikin models we suggest that this is an area warranting clinical evaluation [10,11].

15. Face mask ventilation training

Training in this fundamental skill has traditionally been undertaken using manikins. Accurate feedback mechanisms for candidate performance have not been available. Manikin and infant studies have shown that resuscitator performance and clinical outcomes are improved by the use of a respiratory function monitor [46,47]. Newer training courses are now adopting systems to provide real-time objective performance feedback.

Practice points

- Use an appropriate sized well-fitting mask with an effective technique to minimise leak.
- Know the limitations of resuscitation equipment and how best to use it.
- When possible monitor mask leak and the delivered tidal volume.
- Variable leak and airway obstruction result in highly variable tidal volumes.
- Fetal to neonatal lung transition is a dynamic process; initially PEEP or CPAP assist the clearance of lung fluid and formation of an FRC.

Research directions

- Investigate how to squeeze a self-inflating bag.
- Does applied force during mask ventilation have physiological consequences?
- Investigate the causes of airway obstruction.
- Evaluate training improvements for effective face mask ventilation.
- Evaluate the use of a resuscitation monitor in training and clinical practice.

Conflict of interest statement

Fiona wood is contributing to the development of the Resuscitation Council (UK) ARNI course and associated training system. Colin Morley is a consultant to Fisher and Paykel Healthcare and Laerdal Global Health. He has received payment for lectures from Dräger Medical and Chiesi Pharmaceuticals. He has served on the neonatal group of the International Liaison Committee on Resuscitation.

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